Solar Technology

BLM – Arizona Lands Training
June 25, 2008

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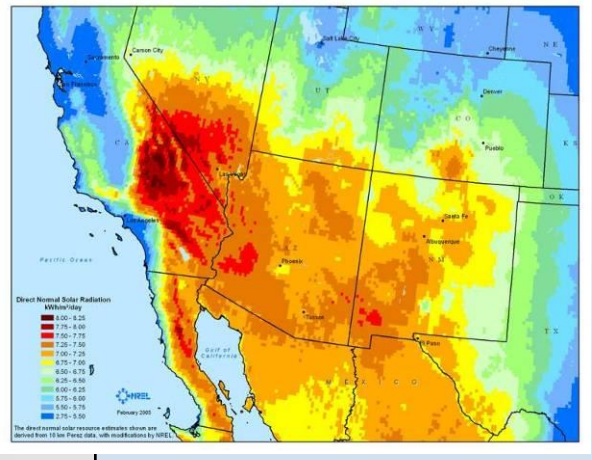
National Renewable Energy Laboratory
www.nrel.gov/pv

Overview of Discussion

- Solar Resource GIS Analysis – Siting
- Concentrating Solar Power (CSP) Technologies
- CSP Development Issues
- Photovoltaics (PV) Technologies
- PV Development Issues
- Solar Market Factors
- BLM HQ Lands & Realty support
  - Funded NREL to provide Solar ROW POD review and consultation as requested
- Q&A throughout discussion

Solar Resource Analysis Focused on the Southwest Region

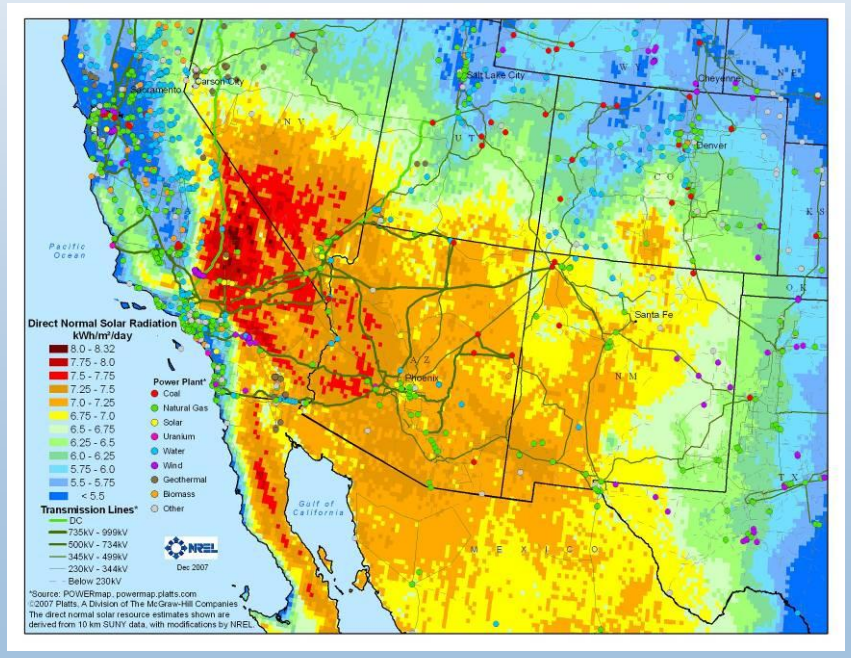


U.S. Southwest GIS Screening Analysis for CSP/PV Utility Scale Generation

Screening Approach

- Initial GIS screening analysis used to identify regions most economically favorable to construction of large-scale CSP or PV systems.

- GIS analysis used in conjunction with transmission and market analysis to identify favorable regions in the southwest



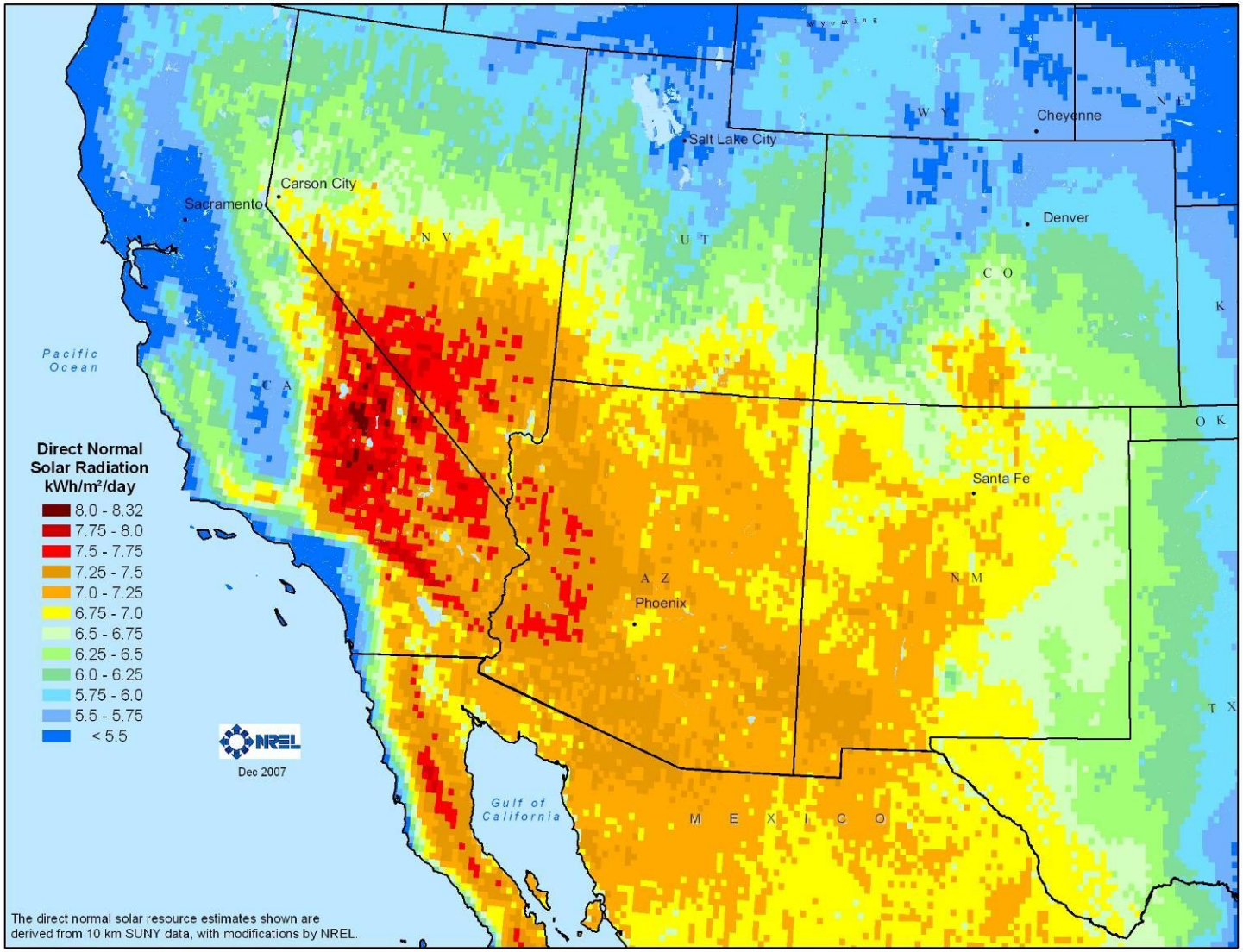
Solar Resource Screening Analysis

All Solar Resources

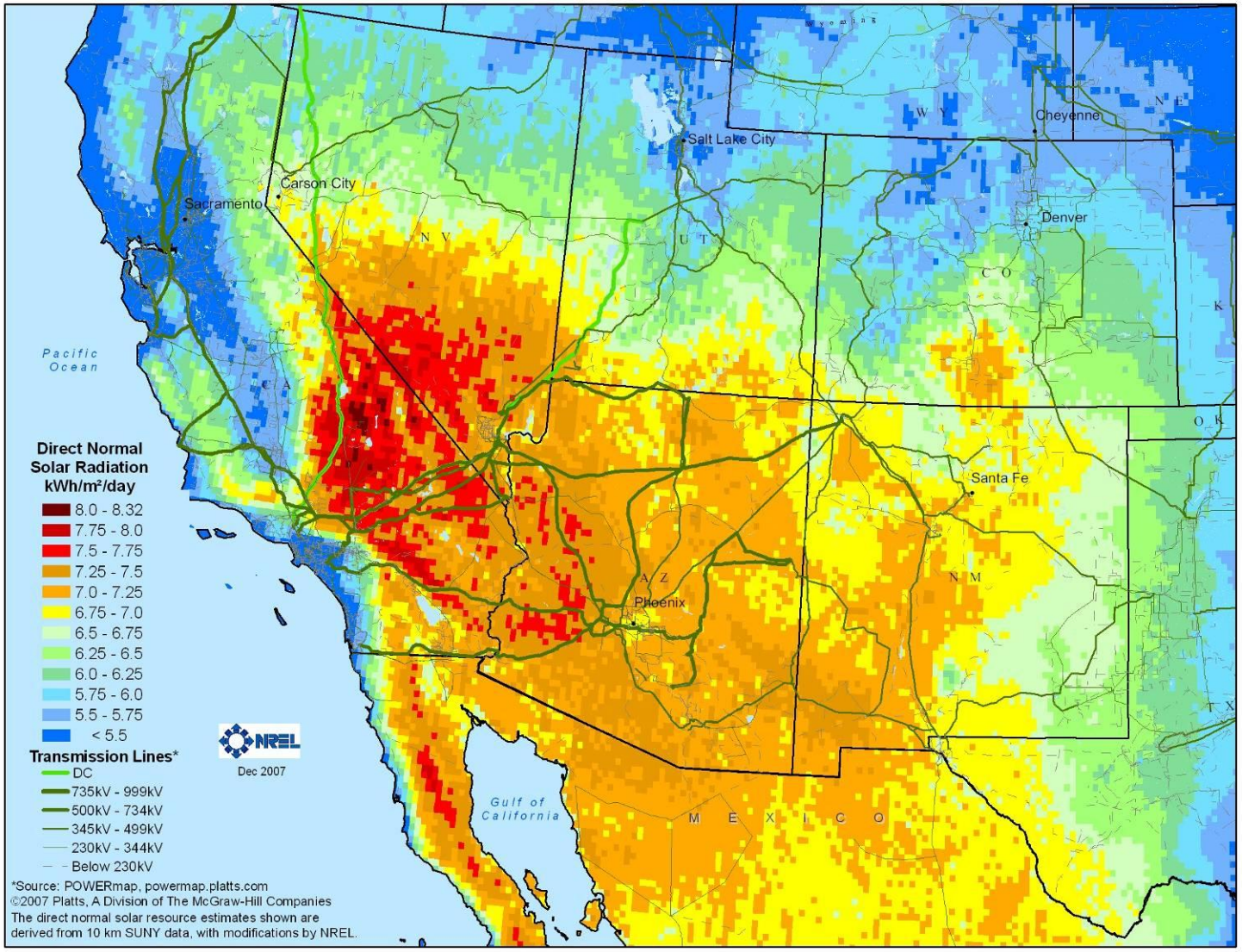
Locations Suitable for Development

1. Start with direct normal solar resource estimates derived from 10 km satellite data.
2. Eliminate locations with less than 6.0 kWh/m^2/day.
3. Exclude environmentally sensitive lands, major urban areas, and water features.
4. Remove land areas with greater than 1% (and 3%) average land slope.
5. Eliminate areas with a minimum contiguous area of less than 1 square kilometers.

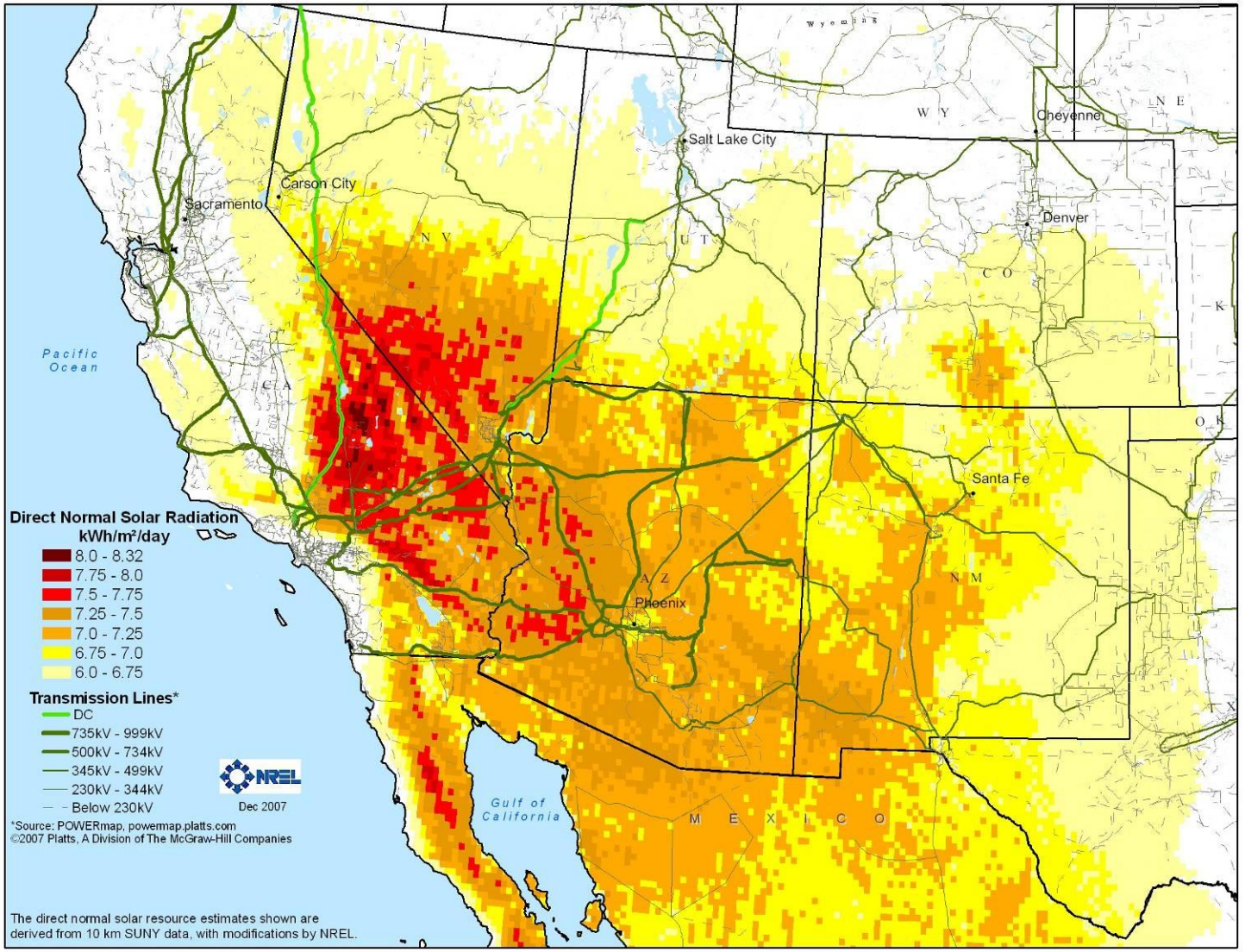
Southwest Solar Resources - Unfiltered Data



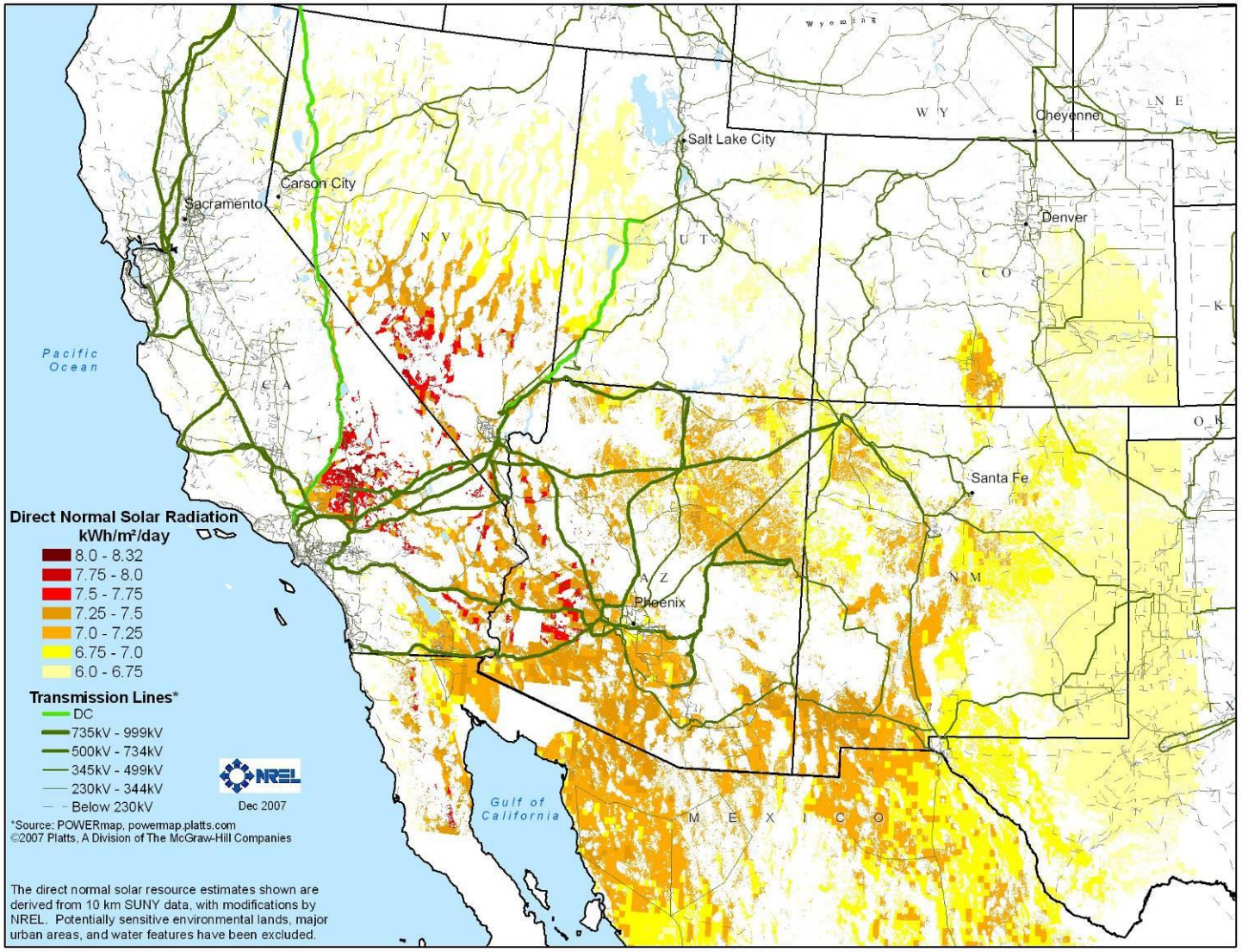
Southwest Solar Resources – Transmission Overlay



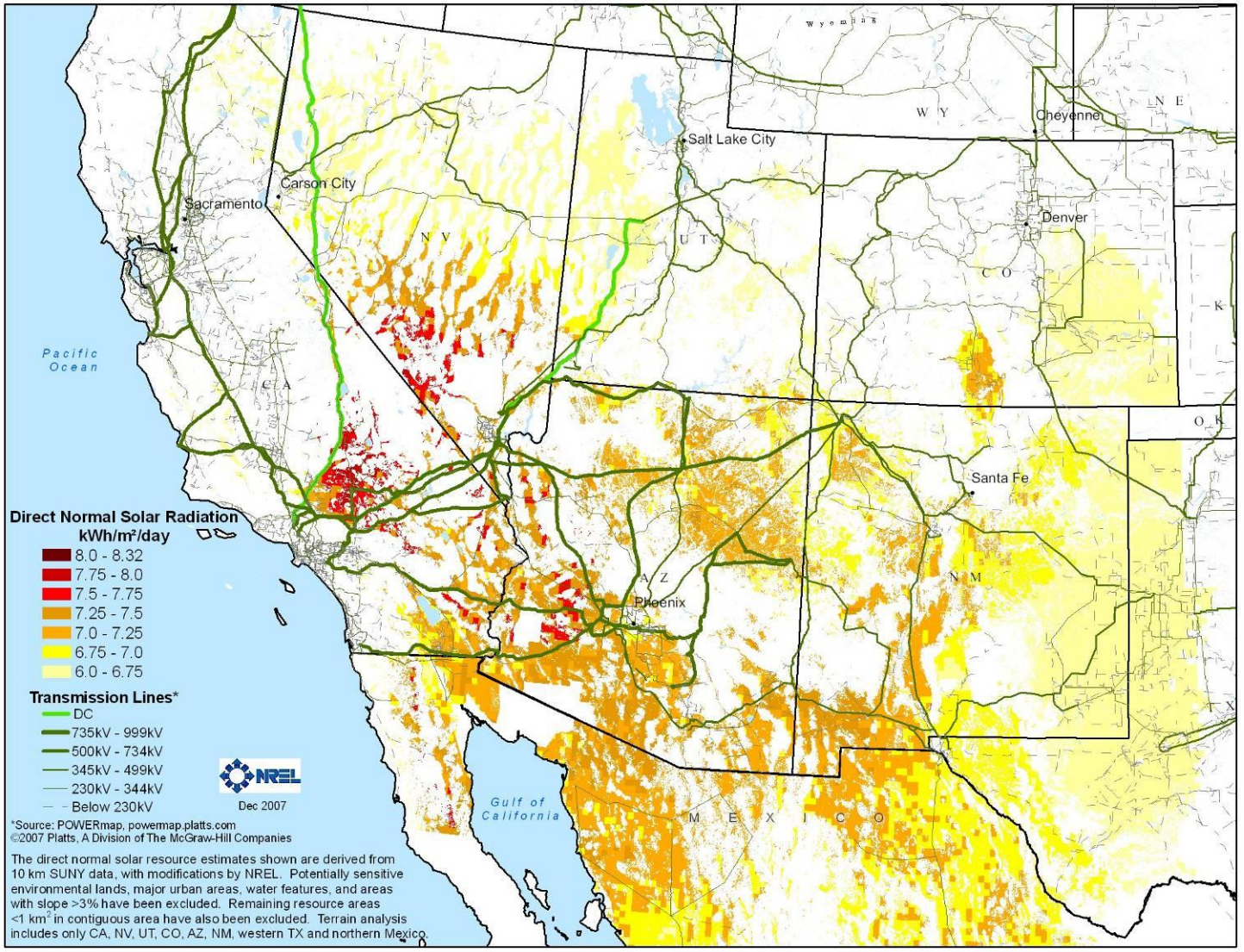
Southwest Solar Resources > 6.0 kWh/m²/day



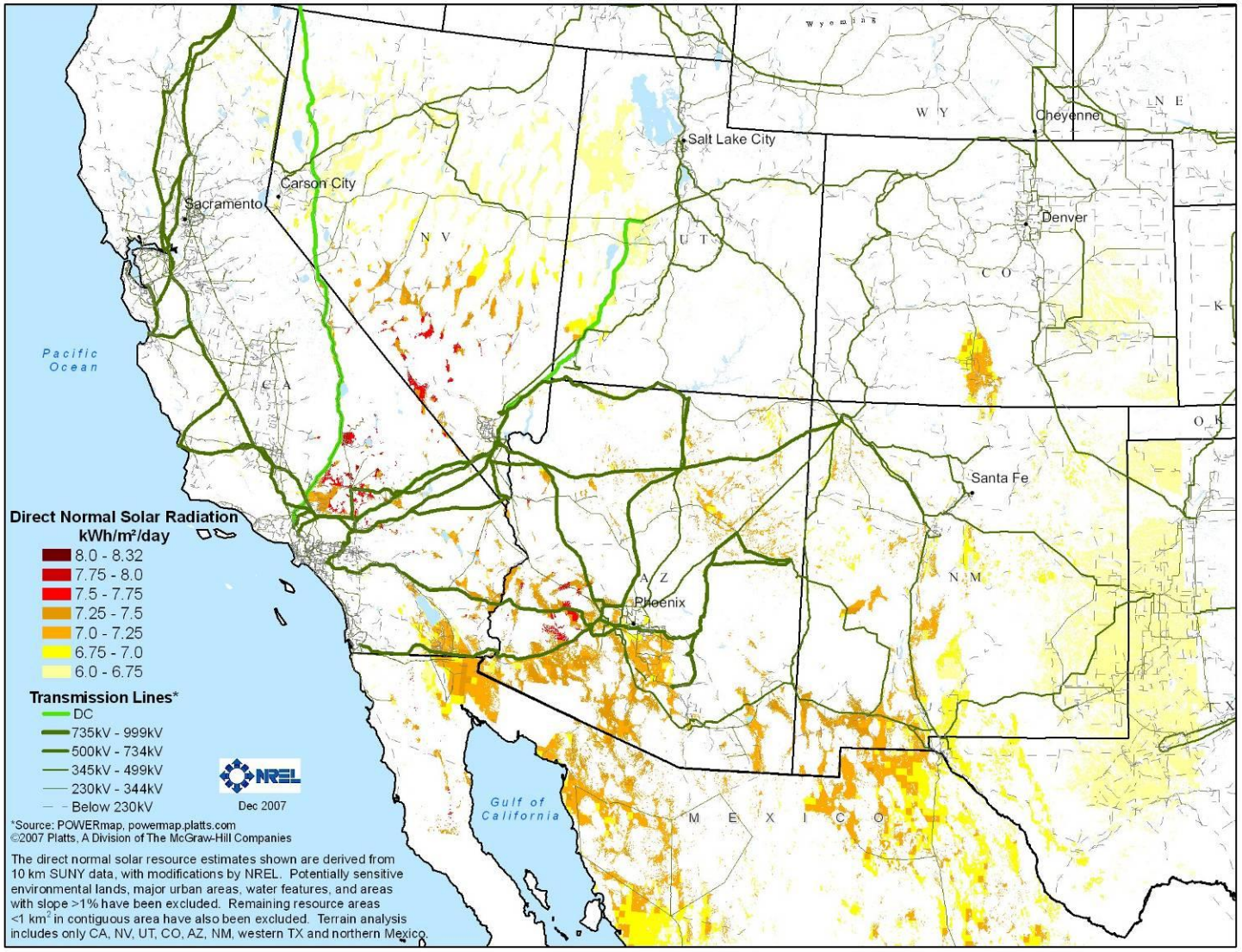
Southwest Solar Resources with Environmental and Land Use Exclusions



Southwest Solar Resources
Previous plus slope < 3%

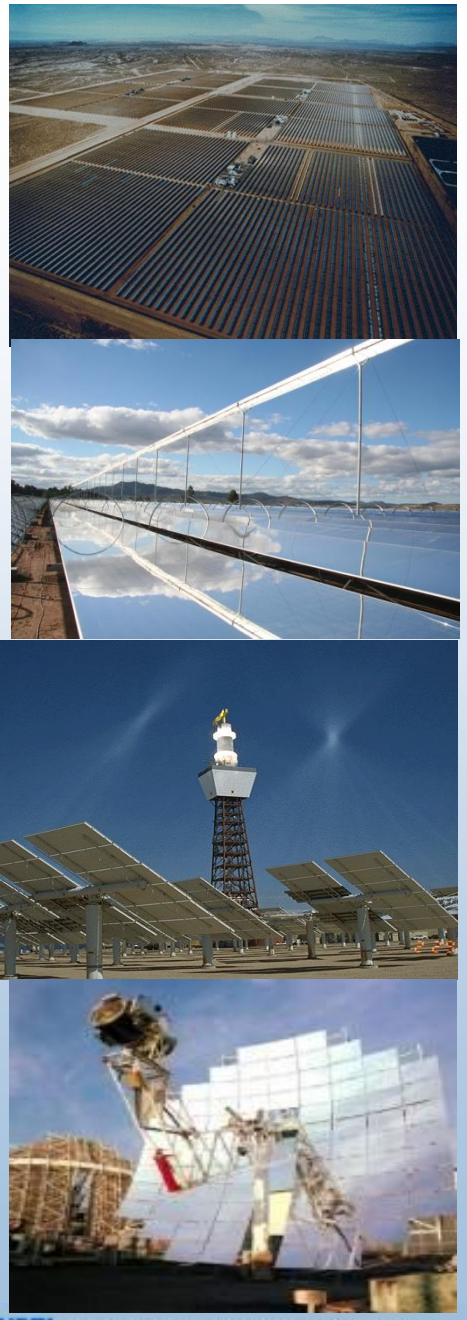


Southwest Solar Resources
Previous plus slope < 1%



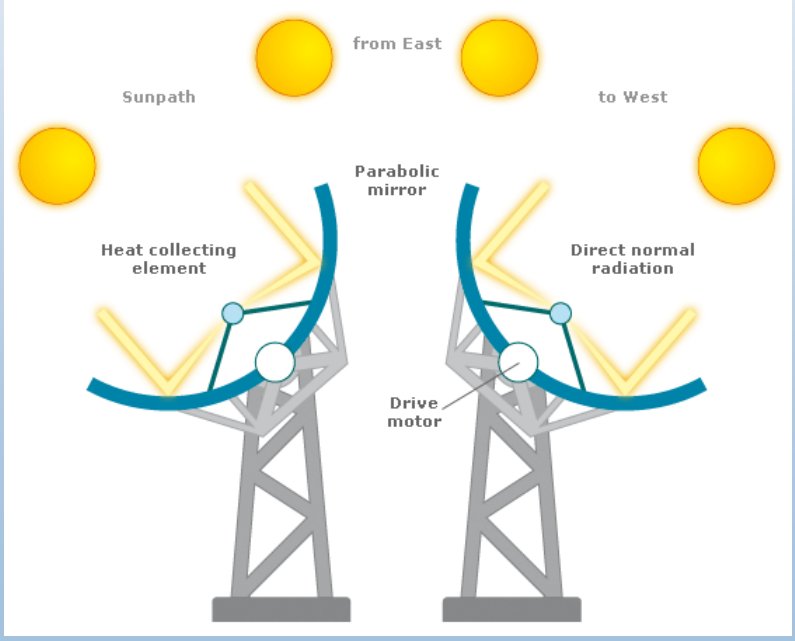
CSP Technologies

- Parabolic Trough Linear Focusing Thermal Electric
- Linear Fresnel Reflector (LFR)
- Power Tower
- Dish-Stirling Engine



CSP – Parabolic Trough

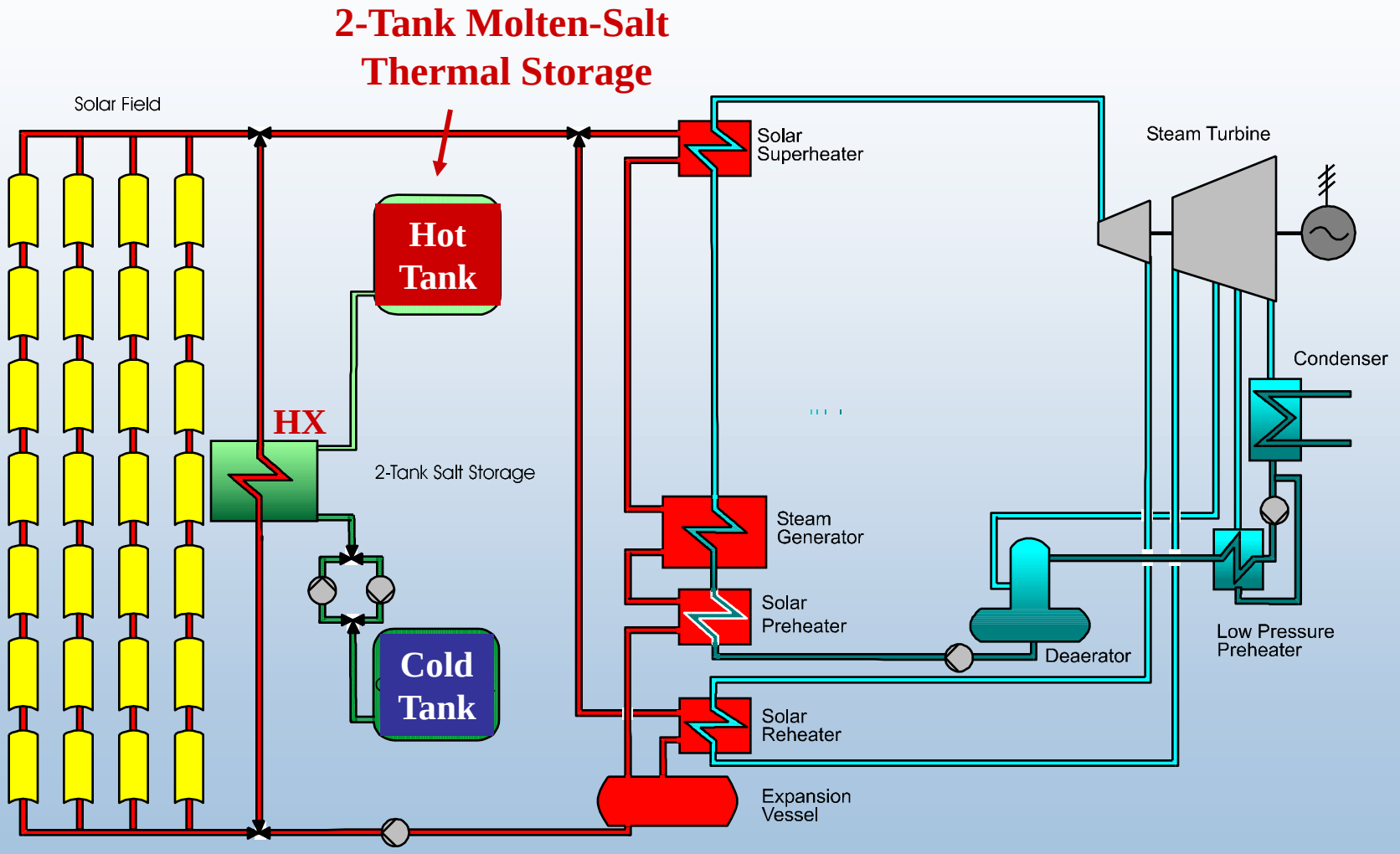
A parabolic trough is a solar concentrator that follows or tracks the sun around a single, rotational axis. Sunlight is reflected from parabolic-shaped mirrors and is concentrated many times onto the receiver tube at the focal point of the parabola. Synthetic heat transfer oil pumped through the receiver tube and is heated to approximately 752 F (400 C). The oil transports the heat from the solar field to the power block where the energy is converted to high-pressure steam in a series of heat exchangers. This steam is converted into electrical energy using a conventional steam turbine.



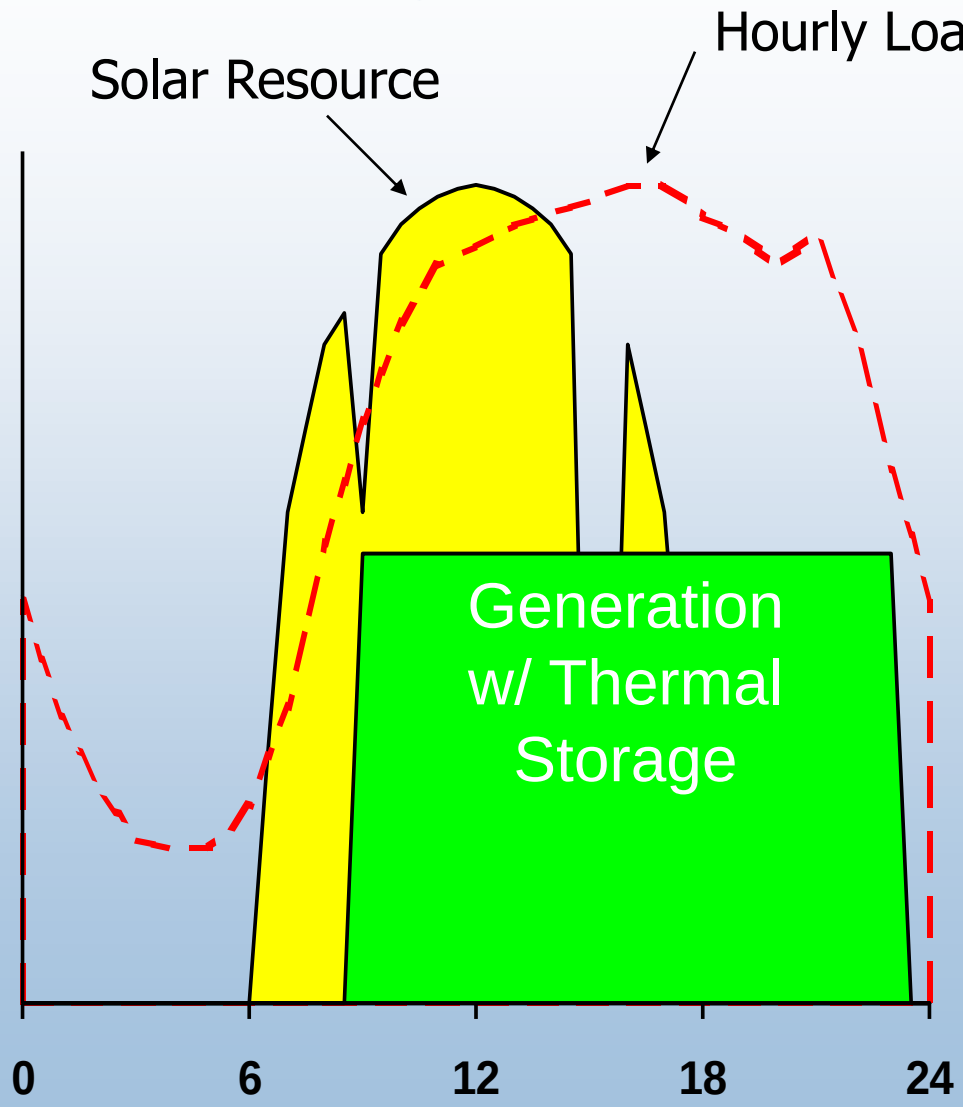
Parabolic Trough Collectors

Perspective on Collector Size

Parabolic Trough Power Plant with Thermal Storage



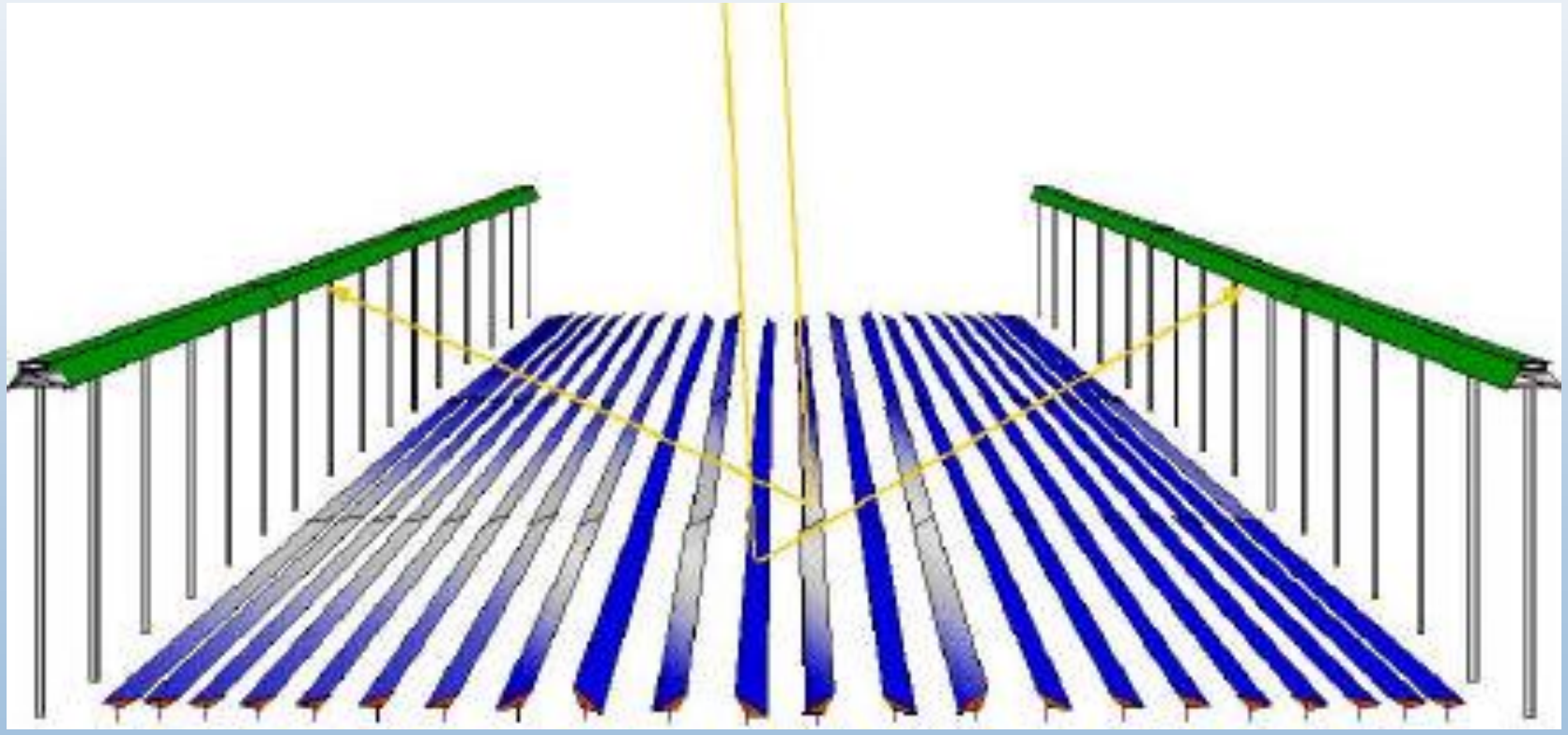
High Value of Dispatchable Power Meeting Utility Power Demands



- Storage provides
  - higher value because power production can match utility needs
  - lower costs because storage is cheaper than incremental turbine costs

CSP - Linear Fresnel Reflector

Simple flat moving reflectors follow the path of the sun and reflect solar heat on fixed receivers above. Concentrated sunlight boils water or other heat transfer fluid in fixed tubes to create high pressure steam to be stored or delivered to conventional steam turbines for power generation.

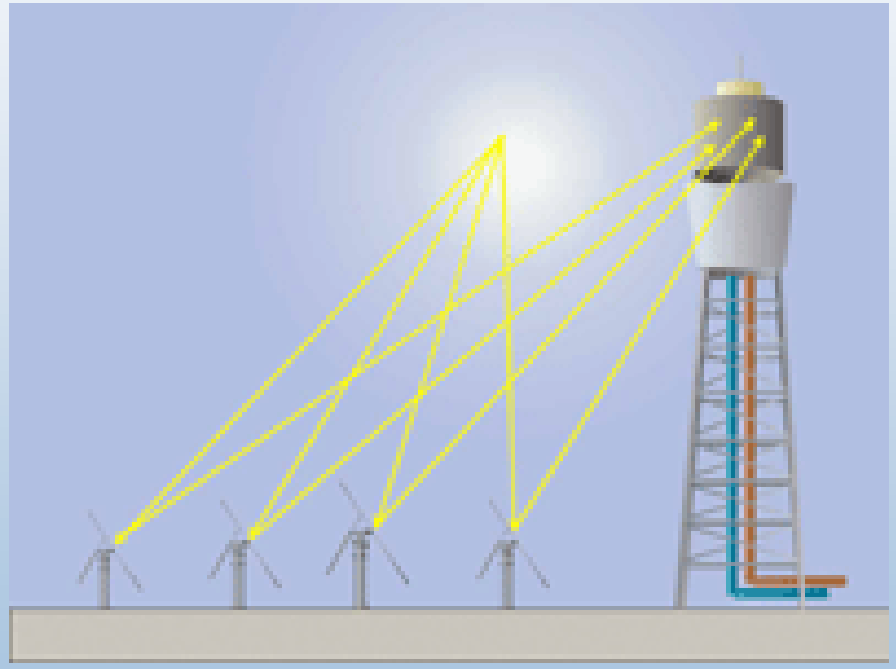


Compact Linear Fresnel Reflector

View of CLFR Installed System

CSP - Power Towers

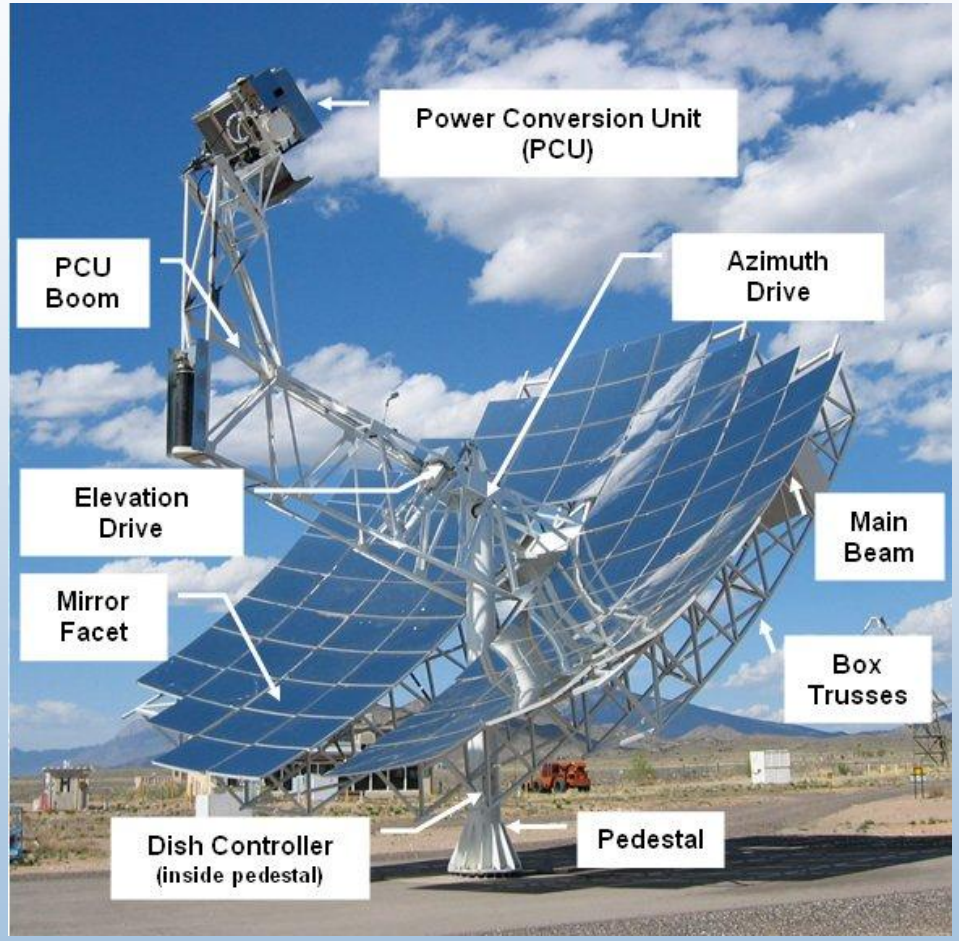
Power Towers consist of an array of thousands of relatively small flat glass mirrors placed around the receiver (solar boiler) which converts the light received into useful heat. These mirrors reflect sunlight onto the collection surface of the solar boiler approximately 300 feet in the air on top of a tower. The concentrated sunlight focused on the collection surface is used to directly heat steam, which then drives a turbine/generator to produce electricity. Some Power Tower receivers use molten salt as heat transfer medium to generate steam through heat exchangers (like parabolic trough). Molten salt effective as thermal storage medium for dispatchable power



Power Tower Systems

CSP Dish-Stirling

The Dish-Stirling is a 25 kW solar power system that has been designed to automatically track the sun and focus solar heat onto a power conversion unit (PCU). This in turn converts the intense heat to grid-quality electricity. The concentrator consists of a 38-foot diameter dish structure that supports 82 curved glass mirror facets, each three feet by four-feet in area. These mirrors concentrate solar energy onto the heater head of a high efficiency, 4 cylinder reciprocating Stirling cycle engine, generating up to 25 kW of electricity per system.



CSP Dish-Stirling

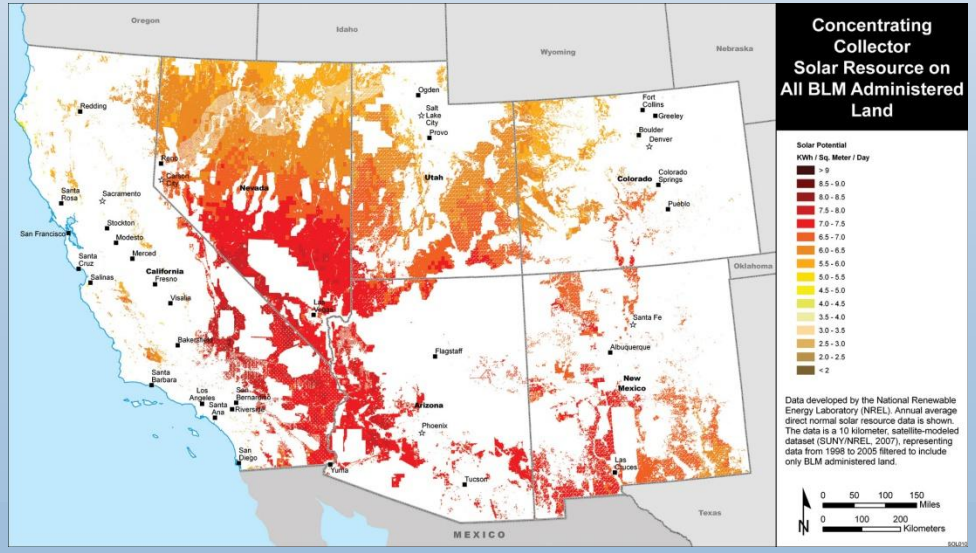
View of Commercial Scale Installation

CSP Deployment Issues

- Solar Resource
- Land
- Water
- Transmission Access/Interconnection
- Road Access
- Environmental requirements
- Financial Aspects

CSP Deployment Issues

- Solar Resource
  - 6.0 kWh/m^2-day or higher
    - Direct Normal Insolation
  - Increasing need for resource assessments
    - Install pyrometer & wind anemometer for 1 year data collection prior to financing



CSP Deployment Issues

- Land
  - Trough/Power Towers
    - ~5 Acres per MW (without thermal storage)
    - ~7-8 Acres per MW (with thermal storage)
  - Dish-Stirling – 10 acres/MW
  - Slope
    - Ideally 1%, 3% feasible for parabolic trough or LFR
    - Slope up to 5% for Power Tower or Dish-Stirling

CSP Deployment Issues

- Land
  - Site Preparation (Land disturbance variable)
    - Parabolic Trough, CLFR, and Power Tower requires cleared land to mitigate vegetation impacts on moving collector systems and heliostats
    - Dish-Stirling land disturbance minimized due to pole mounted systems (18” at base)
  - Minimal environmental impact of pyrometer/anemometer tower

Solar & Wind Resource Monitoring

- 10 m tower
  - 4 guy wires at 5 m
- Measures:
  - Wind Speed
  - Wind Direction
  - Solar Resource
  - Temperature
- Wind monitored at 3 or 10 m

CSP Deployment Issues

- Water
  - Wet Cooled Systems (Trough & Tower systems)
    - 800 gallons per MWh
      - Treatment for Demineralized Water
      - 10% for washing mirrors and boiler make-up
      - Water trucks with pressurized water between rows of receivers & heliostats

CSP Deployment Issues

- Water
  - Dry Cooled Systems (Trough & Tower systems)
    - 80 Gallons per MWh
    - Treatment for Demineralized Water
      - Washing mirrors and boiler make-up
      - Water trucks with pressurized water between rows of receivers & heliostats
      - Evaporative Cooling Towers (make-up water)
    - Increase Electricity cost by 5-10%

CSP Deployment Issues

- Water

Air Cooled Tower

Fans are typically above the packing material where water cascades down from the steam-carrying tubes and draws outside air upward

CSP Deployment Issues

- Water
  - Dish-Stirling Systems
    - No water cooling required
    - 4-5 gallons/MWh for mirror washing

CSP Deployment Issues

- Transmission Access/Interconnection
  - Distance to Transmission major factor in site selection
  - Land Lease of right of entry critical for Interconnection Applications

CSP Deployment Issues

- Road Access
  - Typical road access for any major construction project
  - Conventional sized vehicles for material delivery and construction equipment
  - On site access – paths between rows of collectors & heliostats

CSP Deployment Issues

- Environmental requirements
  - Site Specific
    - T&E Species mitigation
    - Erosion control;
    - Restrict development in ACEC or other environmentally sensitive areas
    - Habitat disturbance mitigation

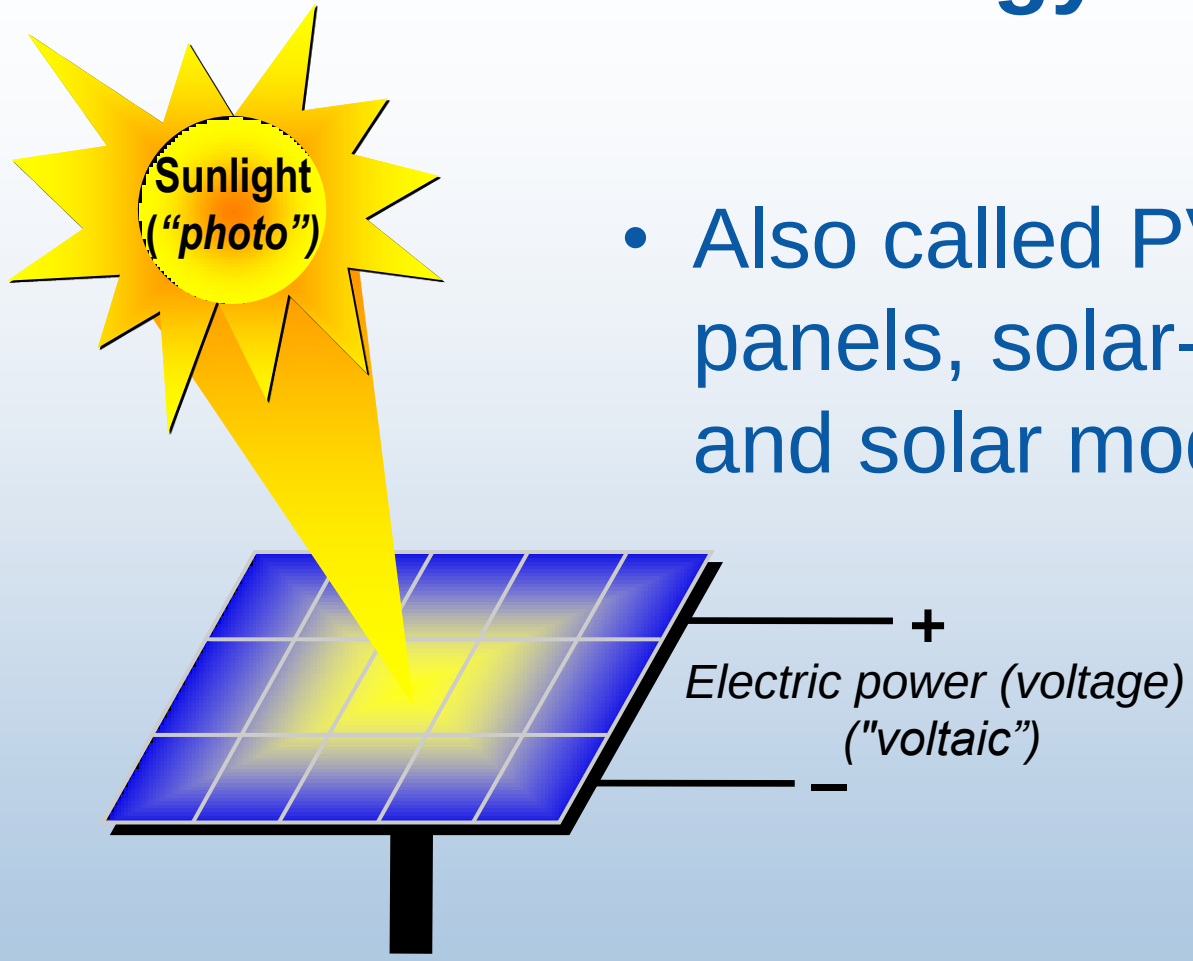
CSP Deployment Issues

- Financial Aspects
  - Power Purchase Agreement
  - Land rights linked w/PPA to accessing financing
  - Land Lease Costs
  - On site construction/operations personnel
  - System dismantling and site remediation at end of PPA or useful life

PV Technologies

- PV Technology Overview
  - Types of PV Modules
  - Flat Plate PV Systems
  - Concentrating PV
- Development Issues

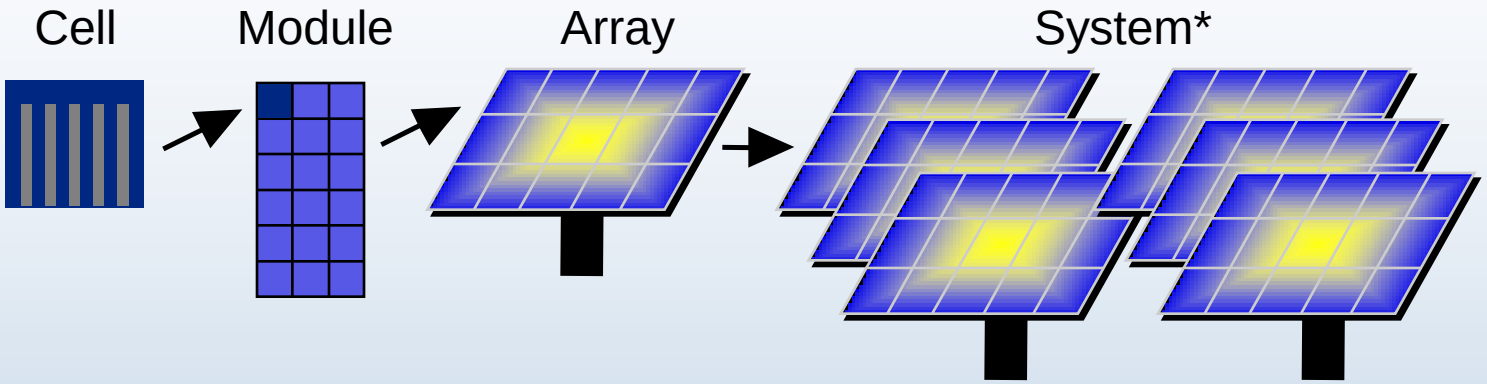
Photovoltaic Technology Overview



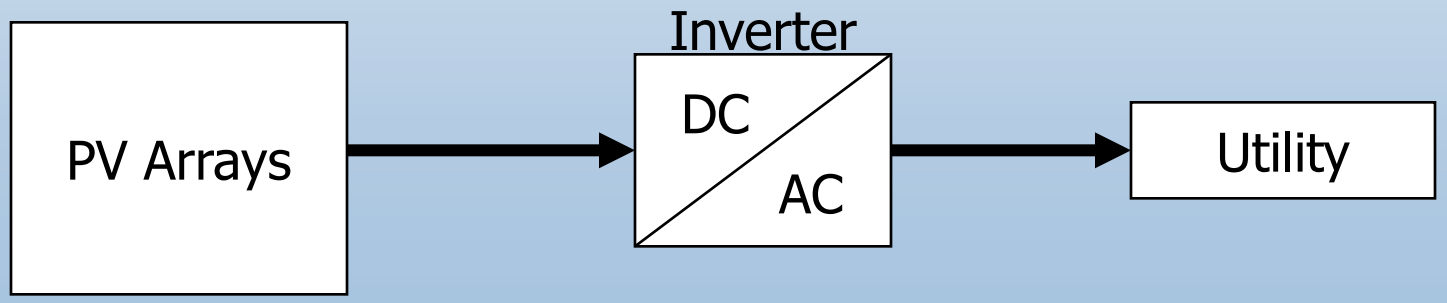
- Also called PV, solar panels, solar-electric and solar modules

- If the sunlight is concentrated then it is called concentrator PV or CPV

Photovoltaic Technology Overview



*Includes storage, voltage regulation, inverters, etc.

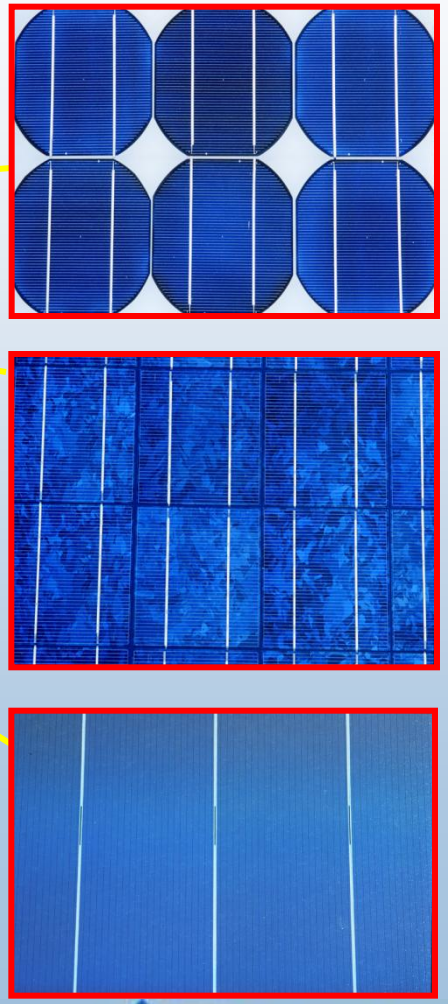


Photovoltaic Modules

- Flat plate types

- Crystalline silicon
  - Single-crystal
  - Polycrystalline

- Thin films
  - Amorphous silicon
    Cadmium-tellurium
    Copper-indium-diselenide



Flat Plate PV Systems

Dangling Rope Marina, Glen Canyon National Recreation Area, UT

Arizona Public Service, Prescott, AZ

Alamosa PV System, Alamosa, CO

5 – 10 acres per MW for PV systems

Land can be left as is or graded

Concentrating PV Systems

Reflective

Refractive

Reflective + optical rod

PV Deployment Issues

- Solar Resource
- Land
- Water
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- Road Access
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PV Deployment Issues

- Solar Resource
  - 6.0 kWh/m^2-day or higher
    - Global Solar for Flat Plate PV
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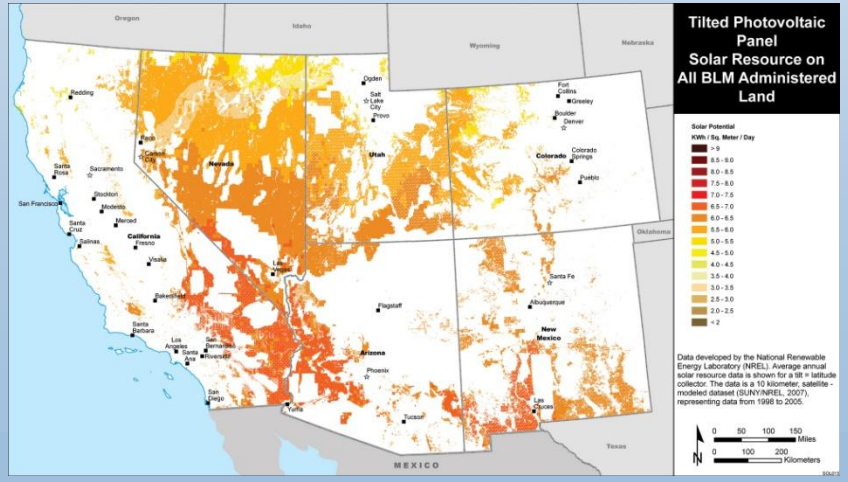
  - Increasing solar resource assessments
    - Install pyrometer wind anemometer for 1 year data collection prior to financing



PV Deployment Issues

- Land
  - 5 to 10 Acres per MW (average over 6)
    - Row spacing or array spacing varies for fixed flat plate and Concentrating PV
      - Mitigate shading
    - Increased spacing for single or dual axis tracking
  - Slope
    - Ideally 1%, 3% feasible for flat plate fixed
    - Higher slope up to 5% for pole mounted

PV Deployment Issues

- Land
  - Site Preparation (Land disturbance variable)
    - PV can be mounted on monopoles to limit surface disturbance
    - Simple to grade for solar field
    - Systems include spacing between rows of panels/receivers for cleaning and maintenance
  - Minimal environmental impact of pyrometer/anemometer tower
  - Expect wind monitoring for tall PV systems

Solar & Wind Resource Monitoring

- 10 m tower
  - 4 guy wires at 5 m
- Measures:
  - Wind Speed
  - Wind Direction
  - Solar Resource
  - Temperature
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PV Deployment Issues

- Water
  - Limited water use (2-5 gallons per MWh)
    - Washing down panels and receivers
    - Some installations may not need cleaning
      - Cost trade off: production versus cleaning cost
    - Water trucks with pressurized water between rows of PV panels and Receivers

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    - Example: limit development in ACEC
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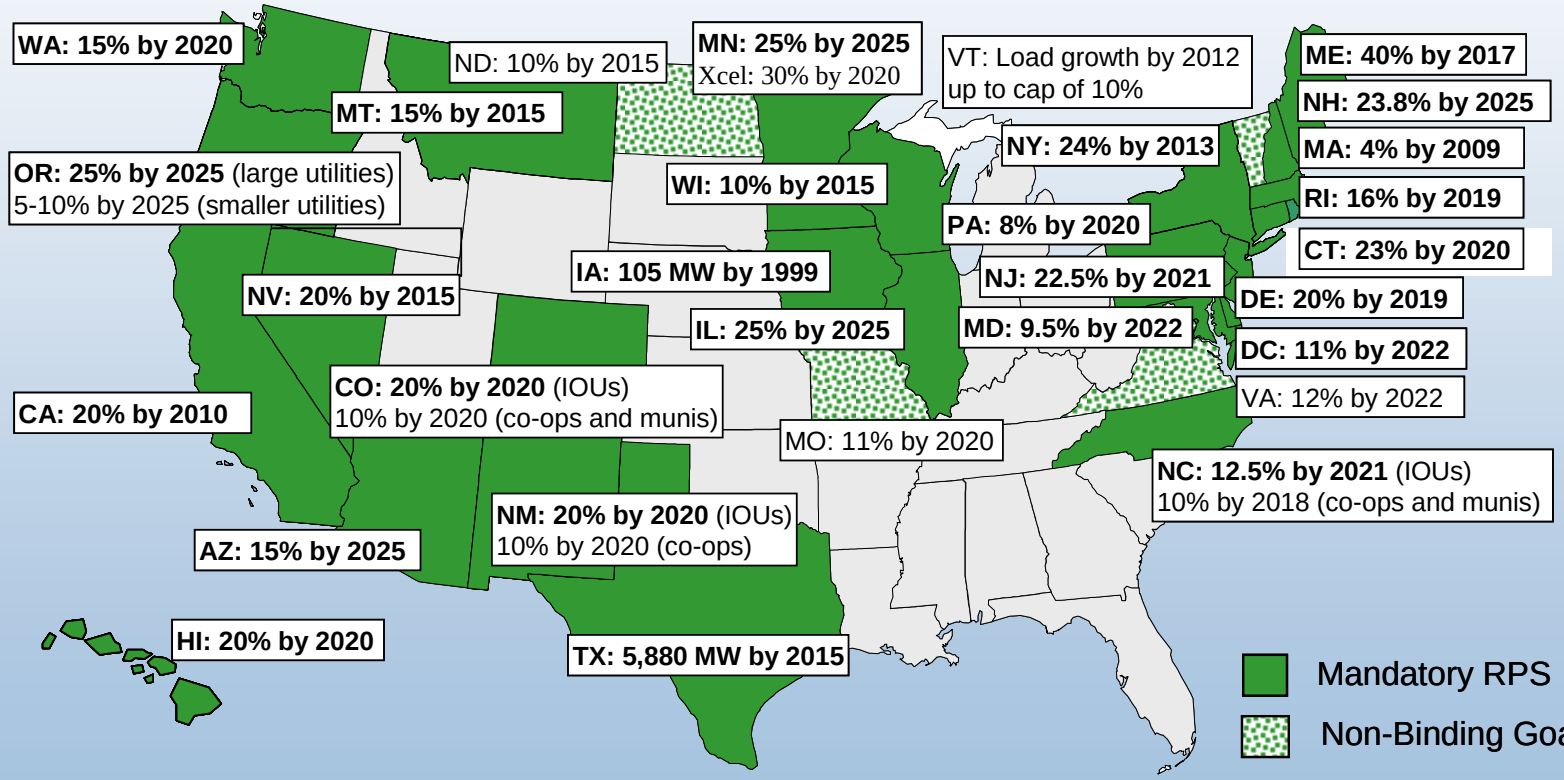
Solar Market Factors

State Renewable Portfolio Standards



Solar Market Factors

- State RPS – Solar Set Aside
  - AZ, CA, CO, NV, NM
  - Typical 5-10% of new renewable generation must be from solar
- Renewable Energy Certificates
  - Value of Green Attributes ($50-200/MWh)

Solar Market Factors

- Federal Tax Incentives
  - 30% Solar Investment Tax Credit (ITC)
  - 5 year accelerated depreciation
- State Tax Credits
  - NM Production Tax Credit
    - ~$.02/kWh for 10 years
- State Property or Sales Tax Exemptions

Solar Market Factors

- State PUC System Benefit Funds
  - Financial Incentives for Renewable Energy generation
- Municipal Utility Financial Incentives
  - Example: LADWP
- Current Renewable Incentives are available at: http://www.dsireusa.org/

BLM HQ Lands & Realty Support

- Funds provide to NREL for:
  - BLM Field Office Solar Training
  - Review of ROW Application PODs and related consultation
  - BLM FOs request NREL support through Rick Stamm, who directs NREL tasks
    - 202-452-5185
    - Rick_Stamm@blm.gov

Summary

- CSP and PV technologies offer a wide range of options to utility-scale markets.
- The solar resource in the Southwest is immense.
- Utility Scale CSP and PV plants to be primarily to be installed in the Southwest.
- Provide significant domestic electrical energy supply